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Exploration for Carbon Dioxide Storage Potential in the Midwestern USA

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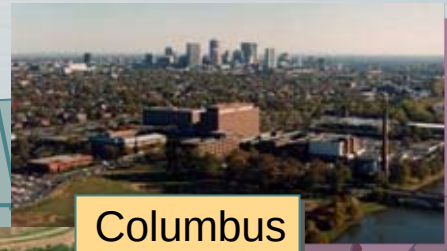
Kentucky Sequestration Consortium
December 7, 2007, Lexington Kentucky

Battelle's operation of major energy labs provides insights into energy challenges

Pacific Northwest

Idaho



Columbus

Brookhaven

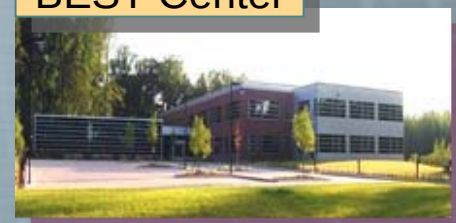
Lawrence Livermore

NBACC

Oak Ridge

National Renewable Energy Lab

BEST Center



$4.0 billion R&D volume
20,000 staff
31 scientific user facilities

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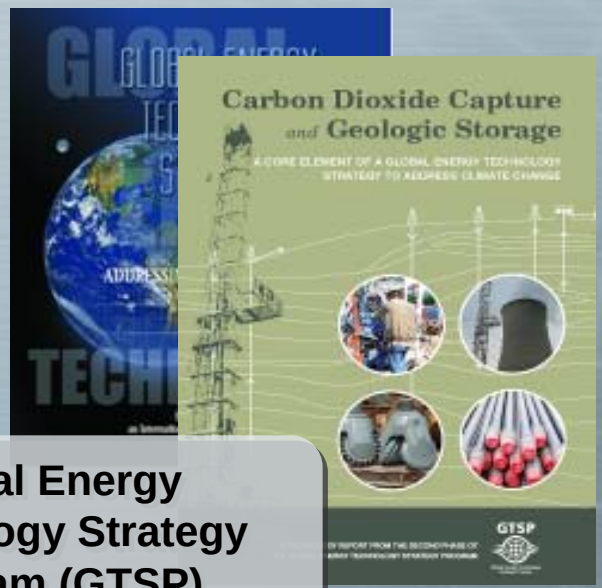
Battelle Plays a Key Role in Several Carbon Sequestration Initiatives

Mountaineer

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

FutureGen

BIGSKYCARBON
SEQUESTRATION PARTNERSHIP

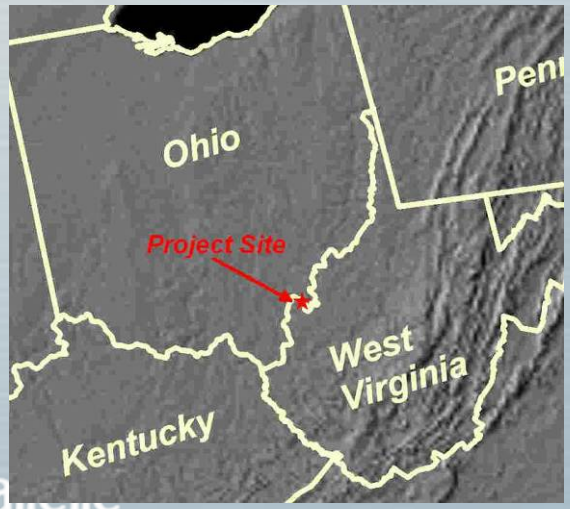


Regional Reservoir Characterization "Piggyback Drilling"

Global Energy Technology Strategy Program (GTSP)

Mountaineer Plant, West Virginia, USA –
Funded by DOE-AEP-BP-Battelle-OCDO-Schlumberger etc.

- 1300 MW pulverized coal plant with NOx and SOx control
- An area of intense power production and future expansion
- AEP has announced a major scale-up and a multi-pronged CCS deployment at this and other sites.



Site-Specific Characterization

Essential for Safe and Effective Operations

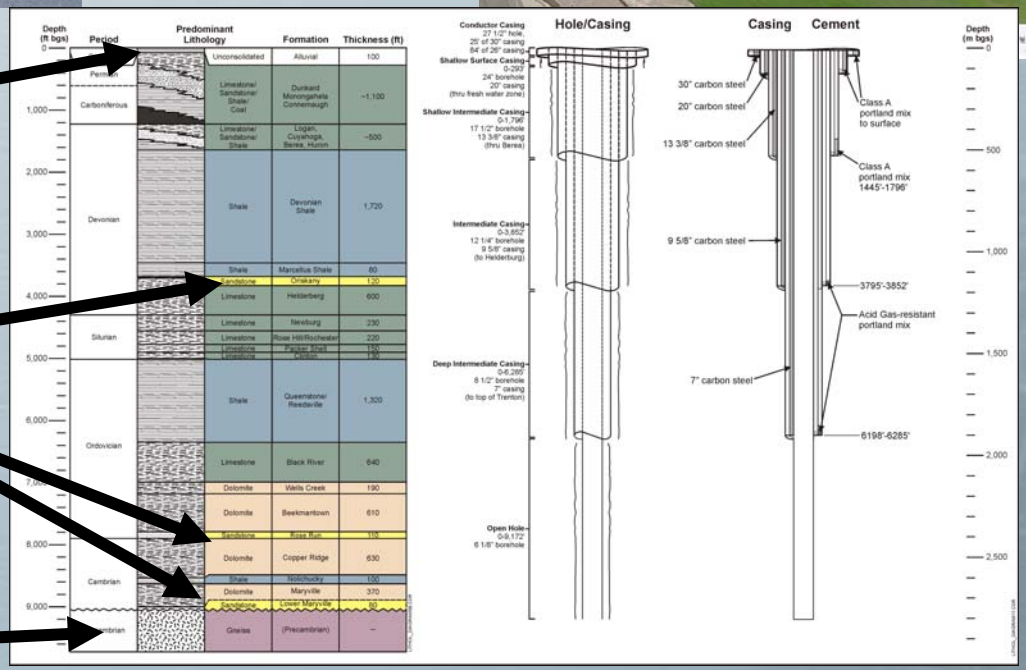
Seismic Survey

Drilling Test Well

Ground level

Possible storage formations > 2,500 ft deep

9,000 feet below the surface



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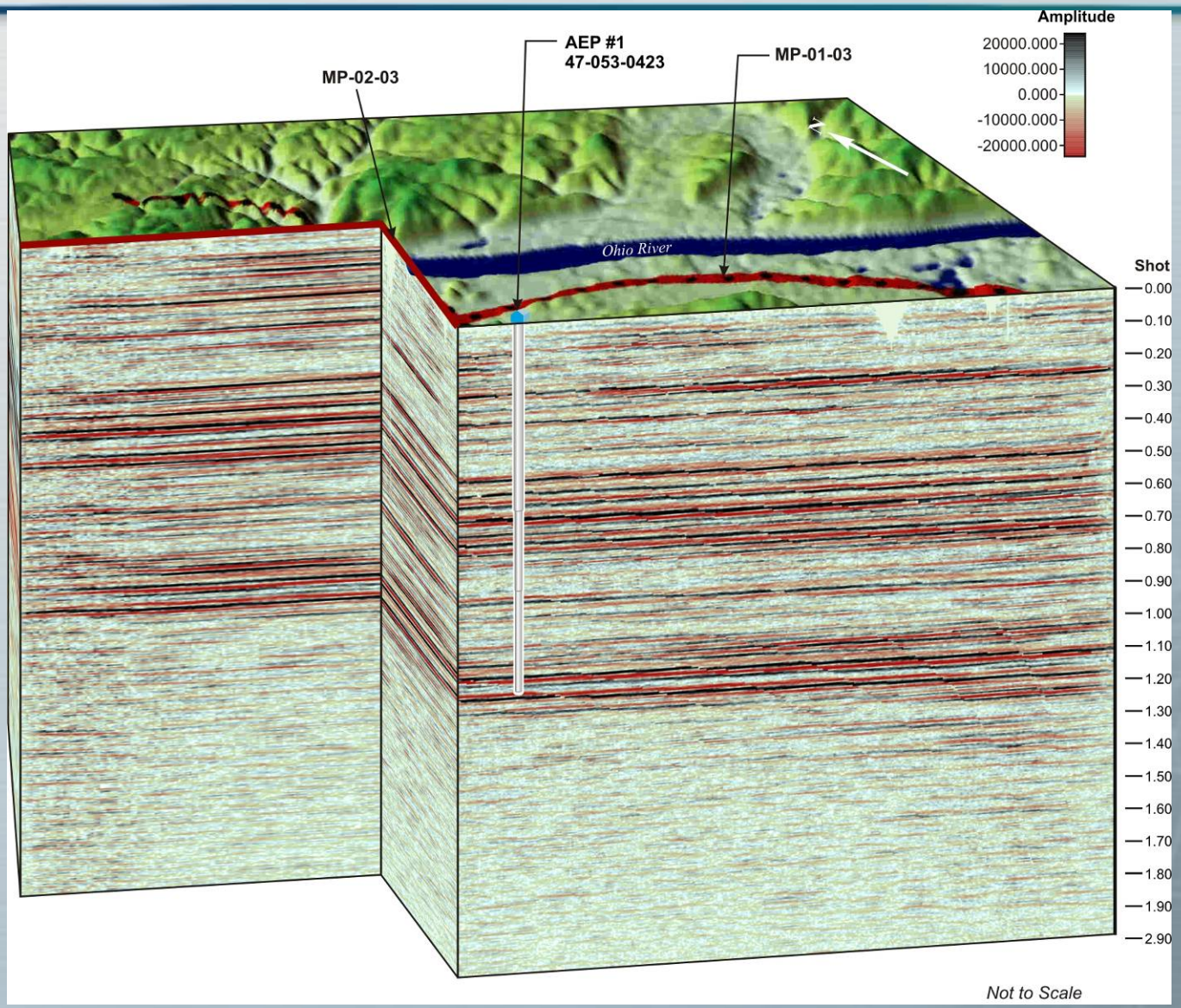
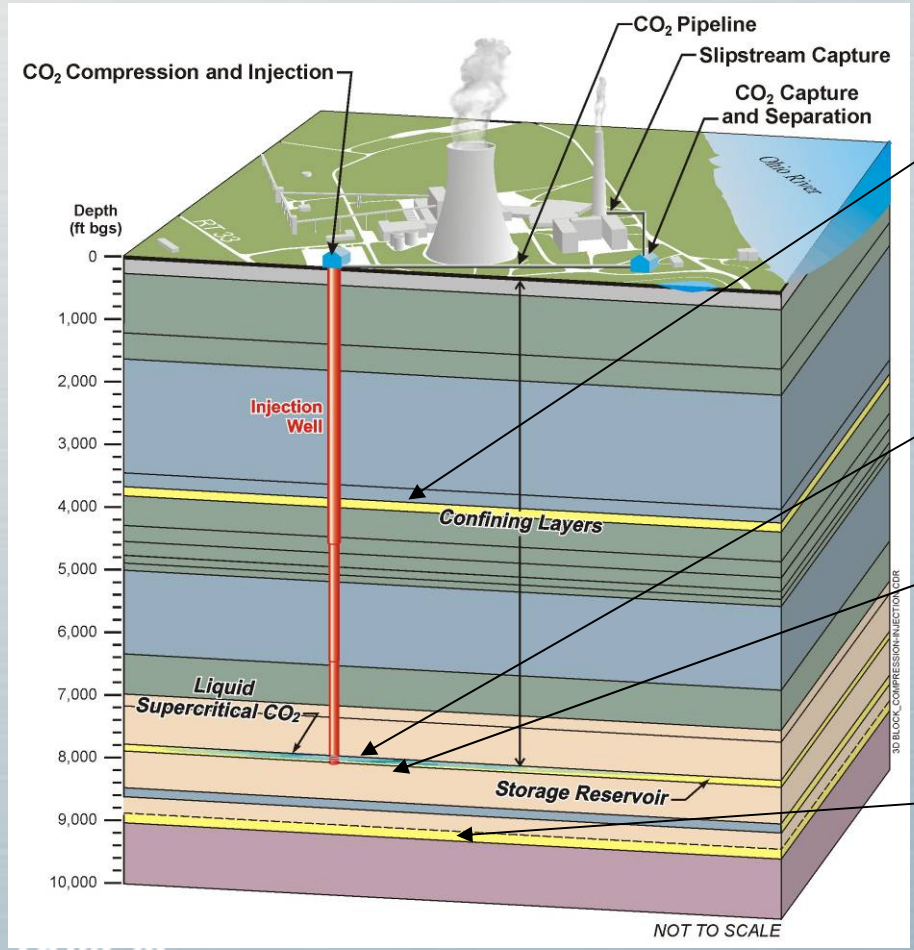
Mountaineer Site - Seismic Survey Demonstrated Impact of Plant Noise and Lack of Faulting



CO_2 Injectivity in the Mountaineer Area

- A number of geologic formations have been evaluated for CO_2 storage potential in the Ohio River Valley region through Mountaineer project



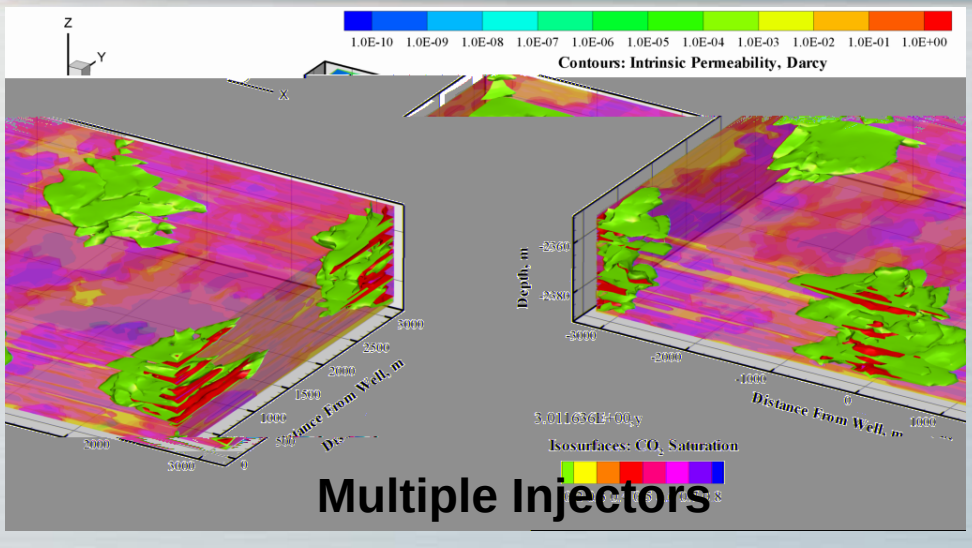
CO_2 injection should also be possible in shallower sandstone and carbonate layers in the region

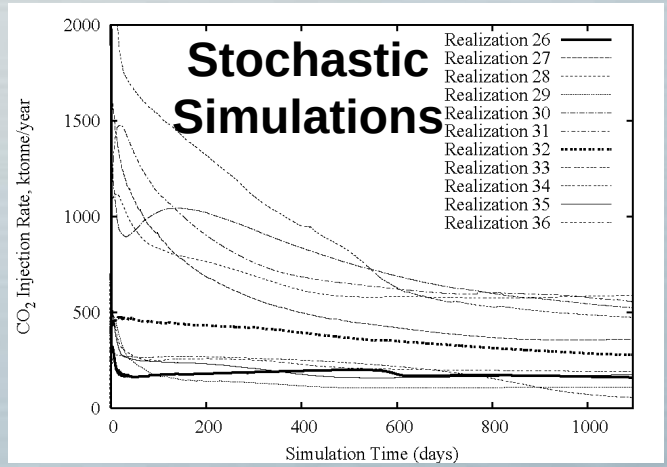
Rose Run Sandstone (~7800 feet) is a regional candidate zone in Appalachian Basin

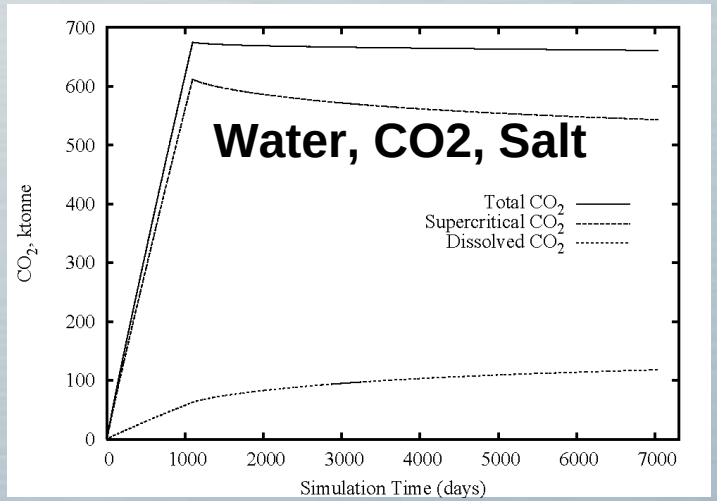
A high permeability zone called the "B zone" within Copper Ridge Dolomite has been identified as a new injection zone in the region

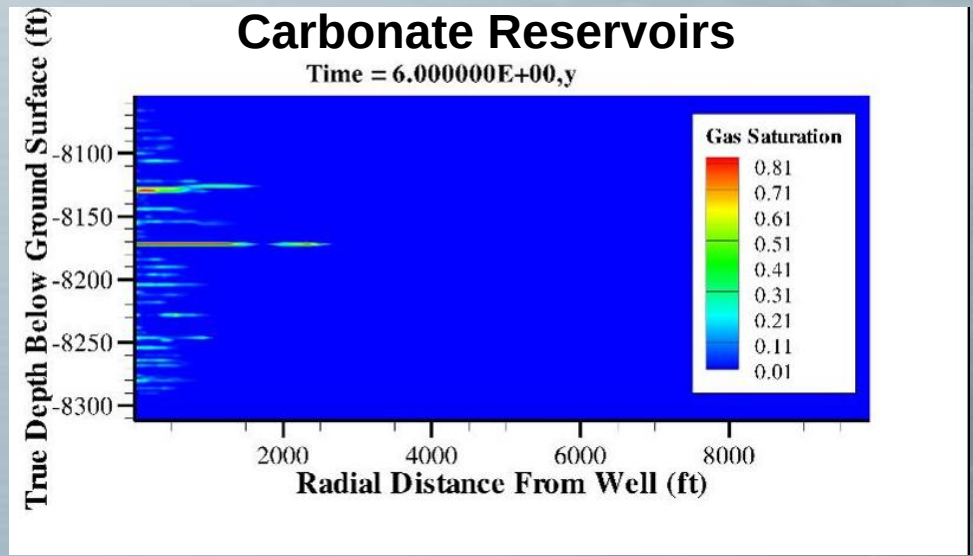
Mount Simon Sandstone/Basal Sand - the most prominent reservoir in most of the Midwest

Simulating Geologic Sequestration to support permitting, outreach, MMV, and Facility Design









Mountaineer CO_2 Storage Assessment Project - A Unique Public Private Collaboration

- **Since 2002, a number of organizations and experts have contributed financially (>$7M) and technically in evaluating geologic sequestration feasibility at the Mountaineer Plant:**
  - **Battelle Memorial Institute – Lead performer and co-sponsor**
  - **DOE/NETL – Primary financial support**
  - **AEP – Host site and co-sponsor**
  - **Ohio Coal Development Office**
  - **BP**
  - **Schlumberger**
  - **Ohio Geological Survey**
  - **Regional Geologists**
  - **Stanford's GCEP Program**
  - ***CO_2 Capture and handling Companies***
  - ***Regional Oil and Gas Companies***
  - ***CRIEPI (Japan)***
  - ***Midwestern Regional Carbon Sequestration Partnership (MRCSP)***

Midwestern Regional Carbon Sequestration Partnership (MRCSP)

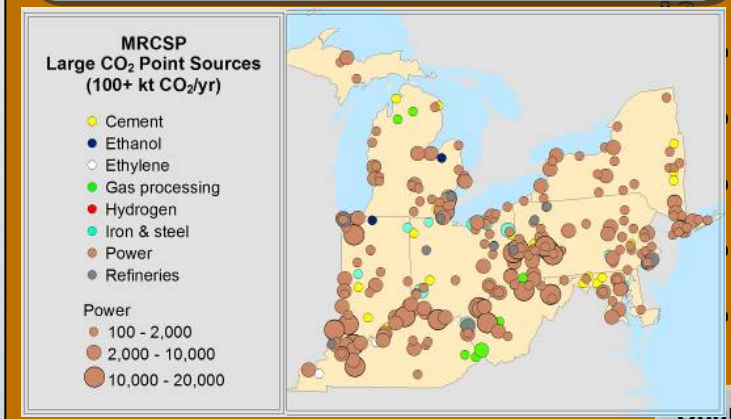
U.S. Department of Energy/NETL

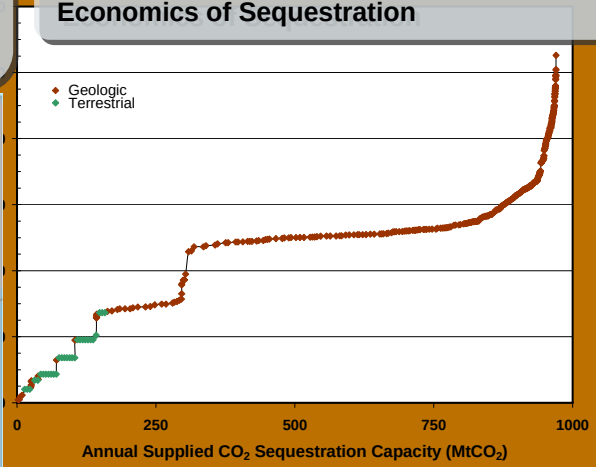
The MRCSP's mission is to be the premier resource for sequestration knowledge in its region

- One in Four Americans
- 1/5 of U.S. Electricity - ¾ From Coal
- ~830 Million Tons of CO_2/year
- ~340 Large Point Sources of CO_2

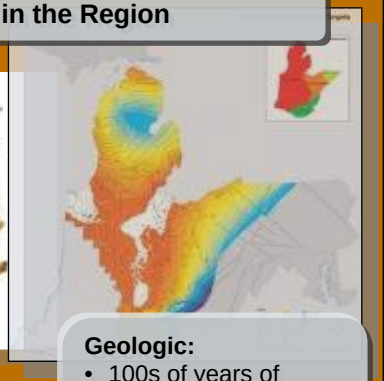
Phase I

Developing a Regional Model of the Economics of Sequestration





Quantifying CO_2 Sinks in the Region



Terrestrial:
- Potential for 20% annual offset for large point sources

Geologic:
- 100s of years of capacity for large point sources in deep saline alone

Reaching Out To and Educating Stakeholders

www.mrcsp.org

Phase II

Implementation

Geological

Terrestrial

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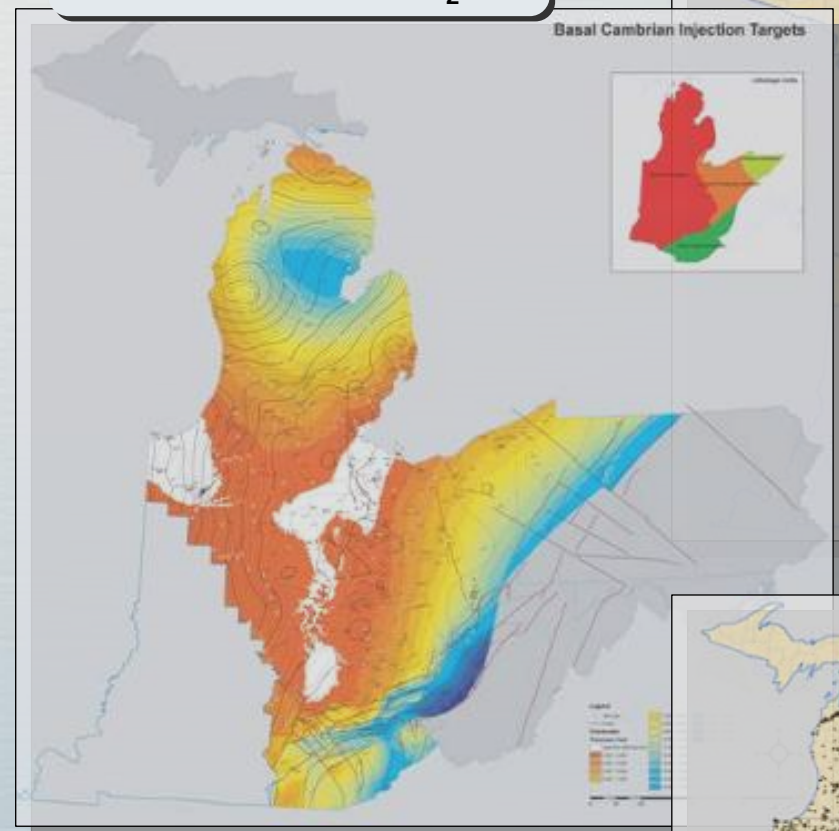
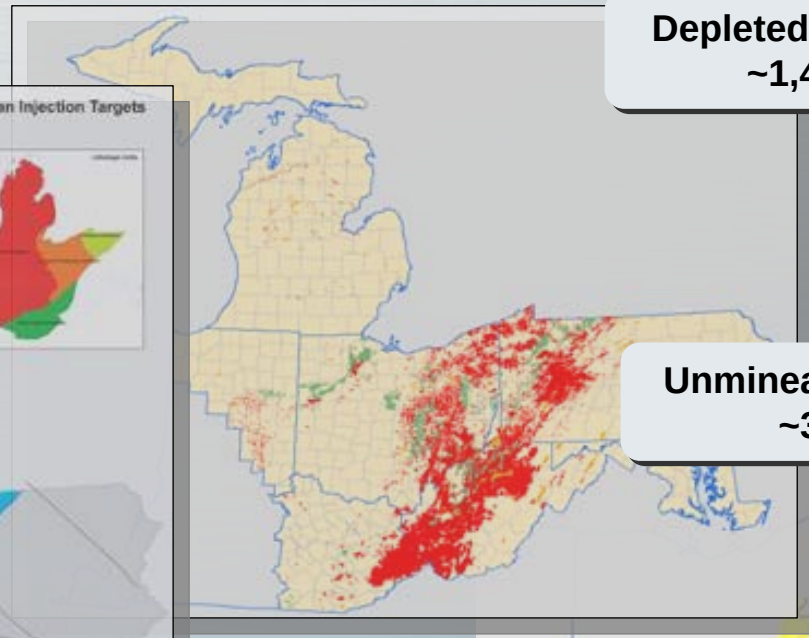
MRCSP Region's Vast Geological Storage Potential is Well Positioned Relative to Sources

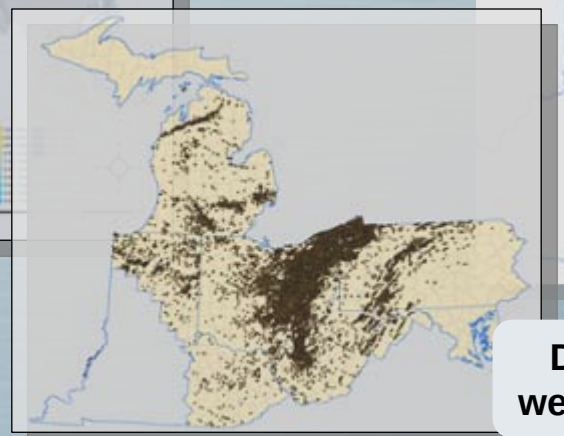
Deep saline formations: >100,000 $MMTCO_2$

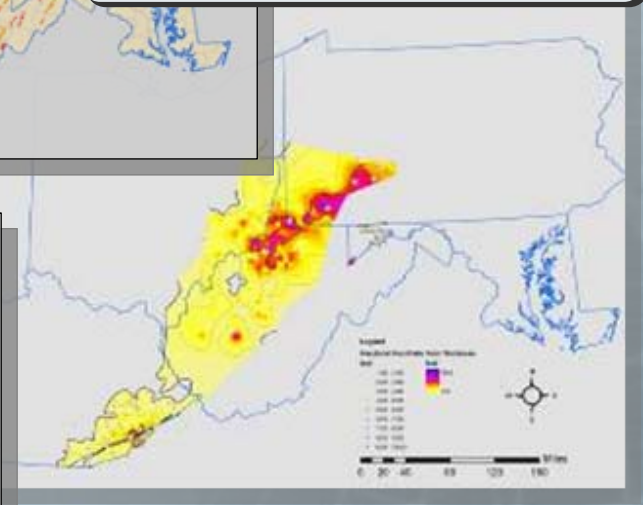


Depleted oil and gas fields ~1,400 $MMTCO_2$



Unmineable coal and shale ~350 $MMTCO_2$





Data from over 40,000 wells have been analyzed

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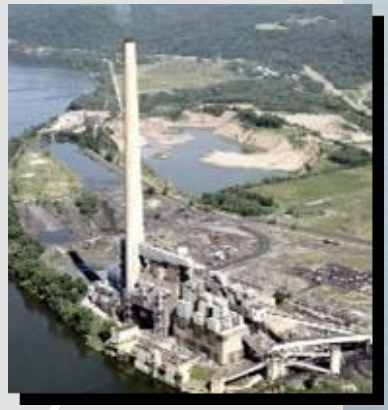
Geologic Storage – three sites are being characterized for injection tests by MRCSP

Michigan Basin

Cincinnati Arch

Appalachian Basin



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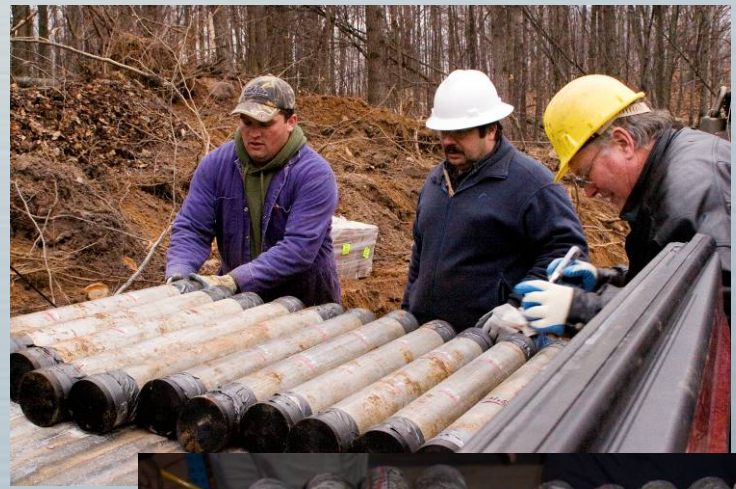
Test Well Drilling at the Michigan Basin Site

- Test well drilled October 30 – November 22, 2006

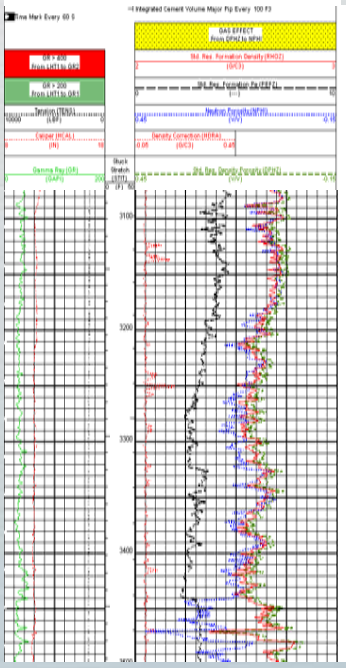
Test Well Drilling

- 180 ft of full core collected.

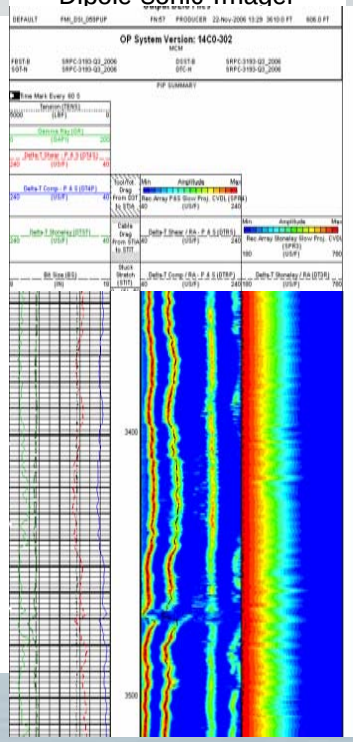


Wireline Logging

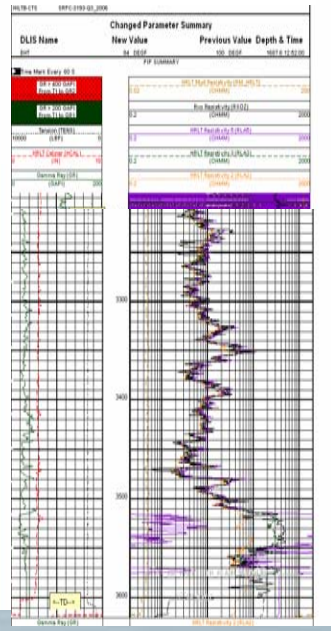
Platform Express
LithoDensity/Caliper
Compensated Neutron/GR



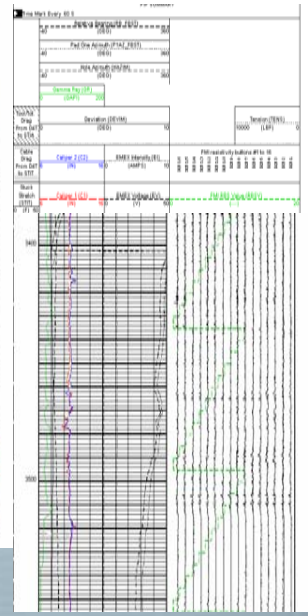
Dipole Sonic Imager



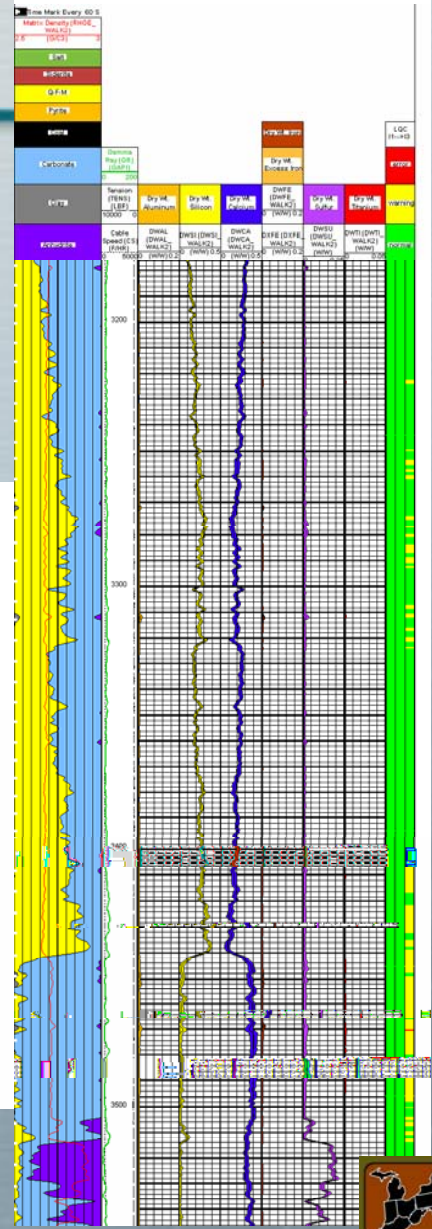
Resistivity Log
Array laterolog



Formation Microimager
Dual Caliper



Elemental Capture
Spectroscopy



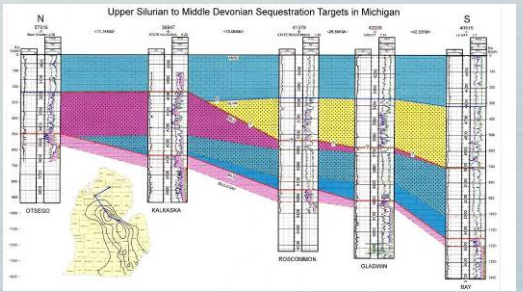
CO_2 Storage Modeling Process

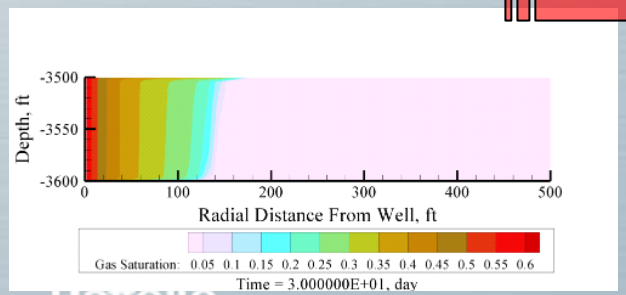
Conceptualize-characterize-Design-Monitor-Calibrate-validate

- Experience with MRCSP and other projects has demonstrated the value of site specific data from test wells.

Example- MRCSP Michigan Basin State-Charlton 30/31 Field Test Site

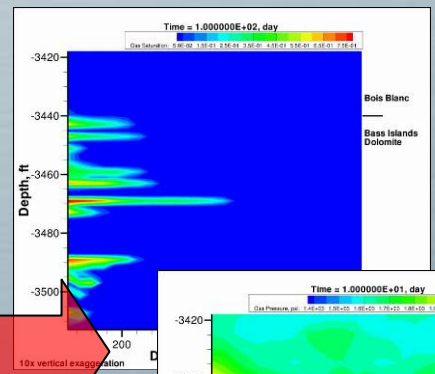
Preliminary Modeling Based on Regional Data

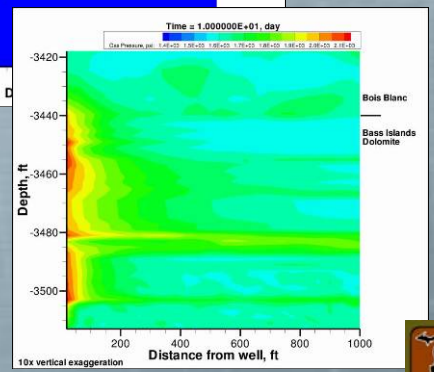




Site Drilling and Testing

Site Specific Modeling





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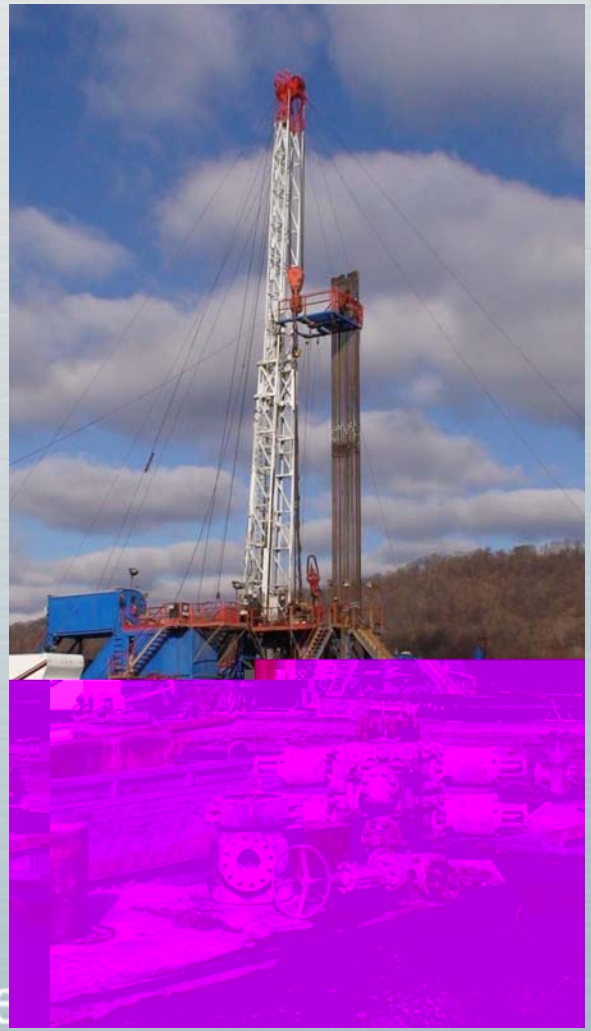
Test Well Drilling – Permitted as Stratigraphic Test Well by State of Ohio

Surface Casing Rig

Deep Well Rig

Test Well Drilling at R.E. Burger Plant, Appalachian Basin

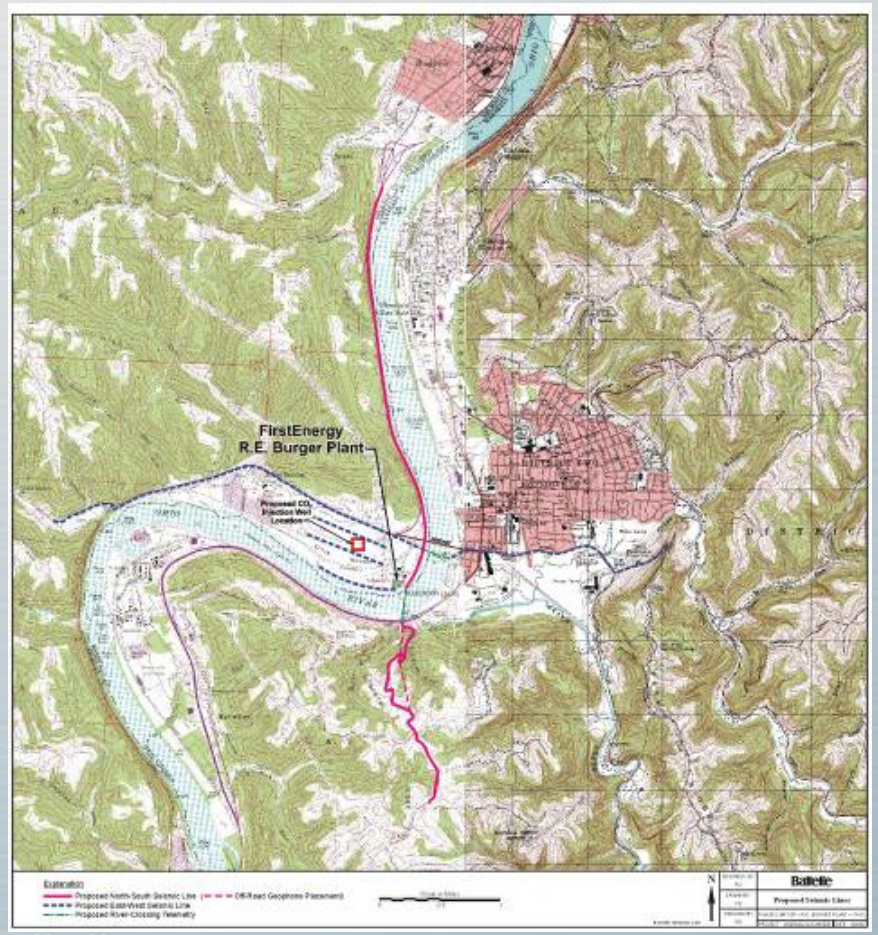
Deep Rig- TD = 8,384’ 2/5/07

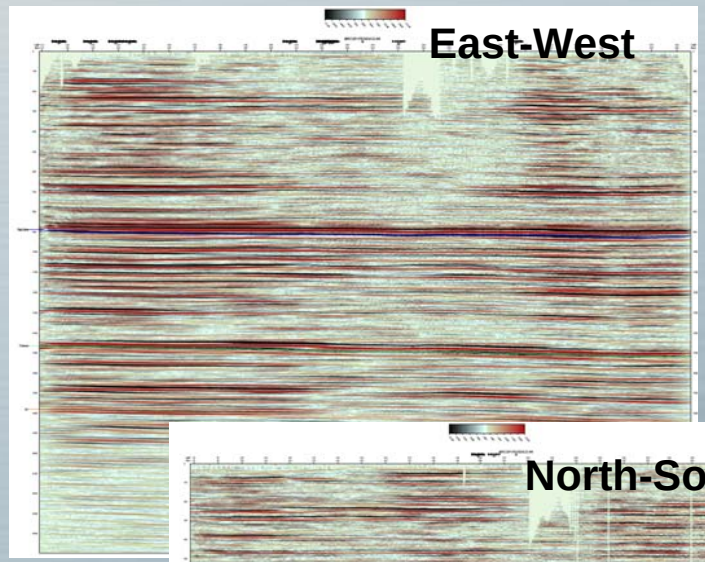


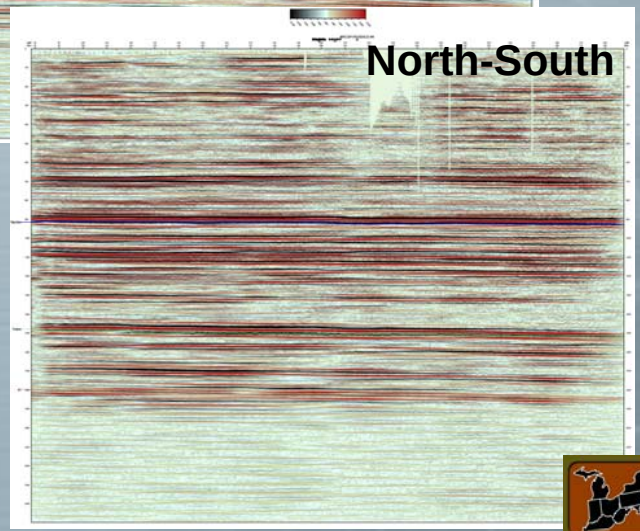
Wireline Logging

Site Characterization- Seismic Survey at Burger Plant

- 10-mile seismic survey completed in August 2006
- Additional 1-mile of “quasi-3D” to investigate reservoirs and 3D options







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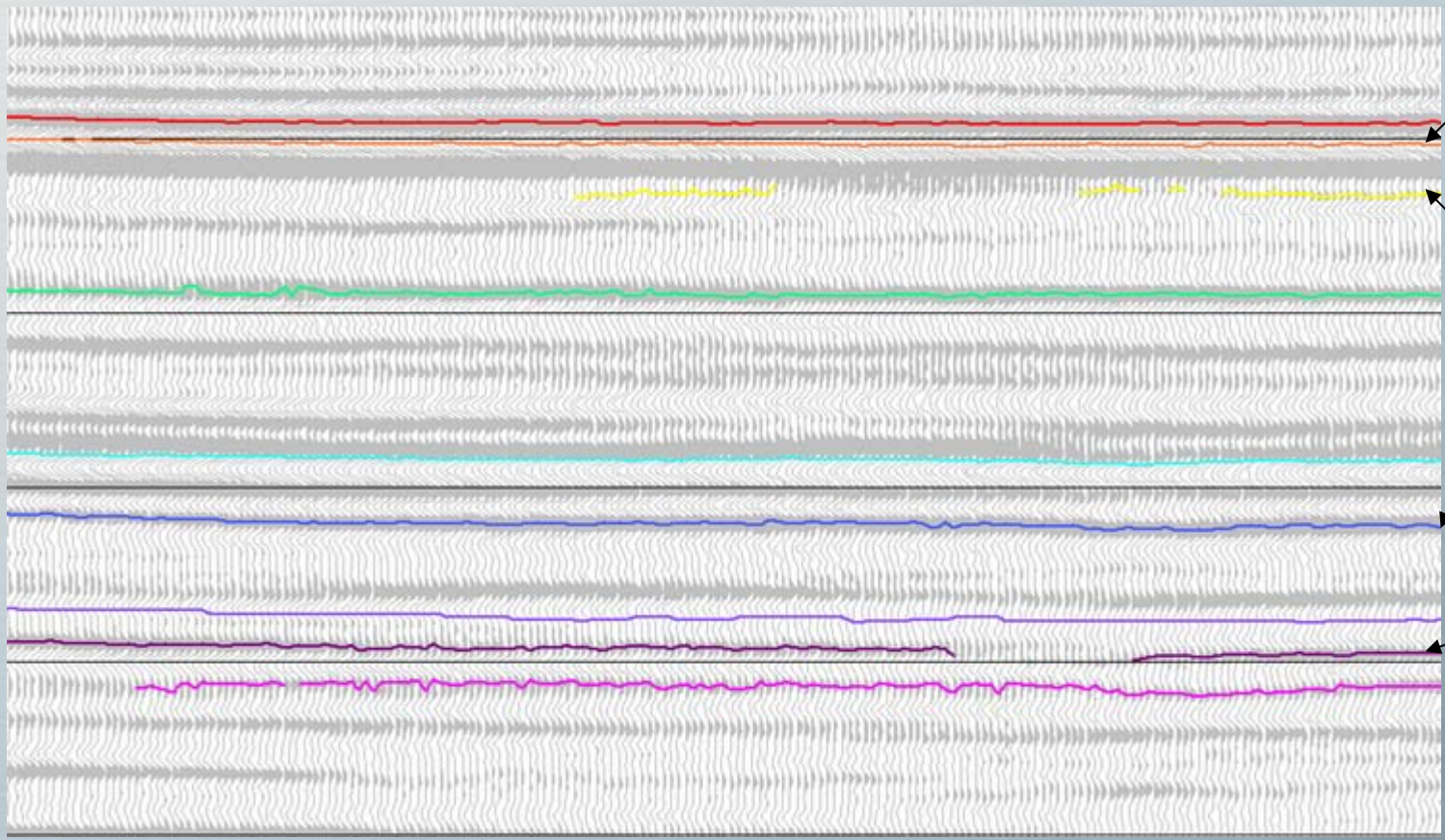
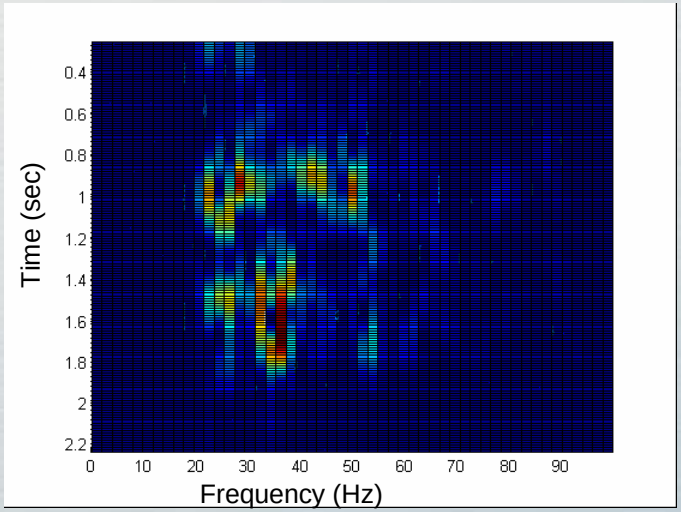
Site Characterization- Detailed Seismic Interpretation

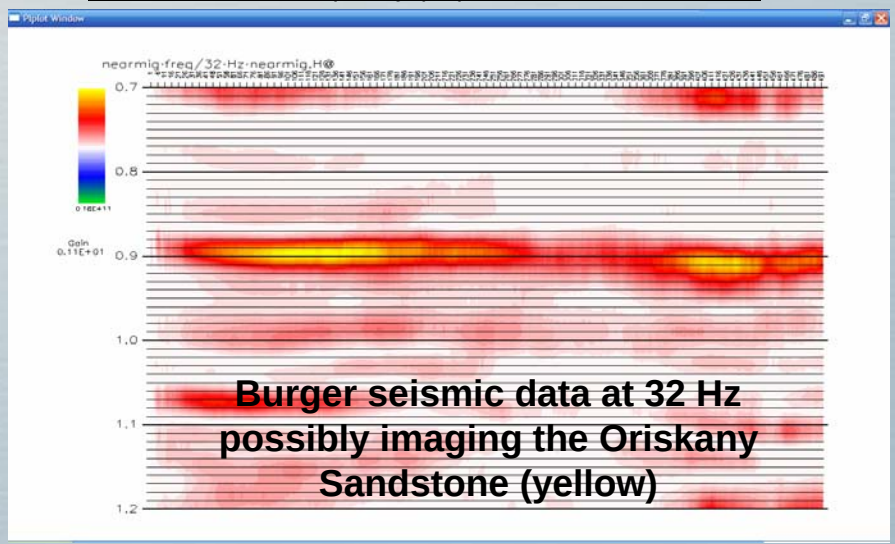
- The Oriskany Sandstone (between the Onondaga and Helderberg is right at the resolution limit of this data
- The White Clinton is much easier to see and post injection changes may be detectable



*Initial Results

Site Characterization- Low Frequency Seismic Analysis





- Low frequency response of a formation is largely dictated by pore fluids
- Different formations should peak at different frequencies
- Imaging methods explored to better define sandstone injection targets

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Proposed Phase III Geologic Test Sites

Ohio Ethanol

Indiana IGCC

- Primary site
  - Injection starts in early FY2010
  - Plans are to inject 1 million tons of CO_2 over a four-year period
  - Target is the Mt. Simon reservoir, the largest deep saline target in our region.
- Optional site
  - Injection starts in FY 2012
  - Possible 2 million tons of injection over four-year injection period
  - Multiple injection zones and caprock layers

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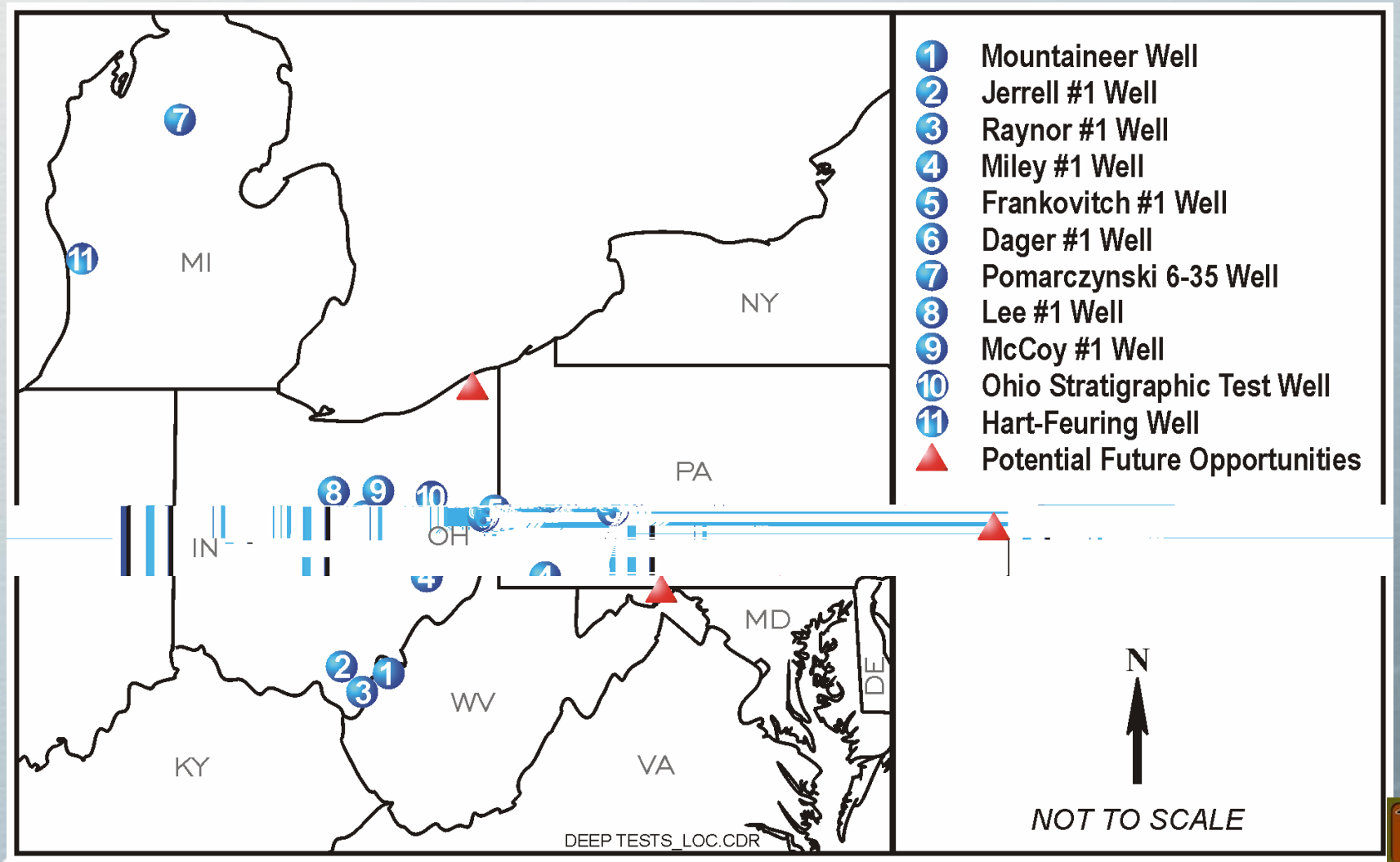
Piggy Back Program - Leveraging the Oil and Gas Exploration Industry

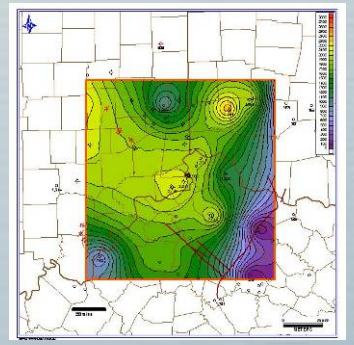
- Team up with oil and gas industry to collect data
- DOE gets access to existing drilling operations – saves significant cost (counts as cost share)
- Oil and gas operators get detailed wireline logs
- Data go back to build regional understanding of geology and improved capacity assessment

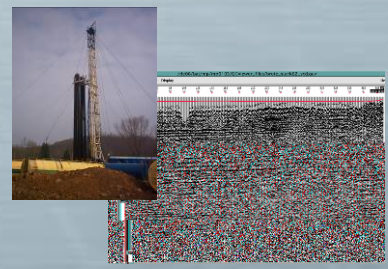
Regional Characterization Efforts

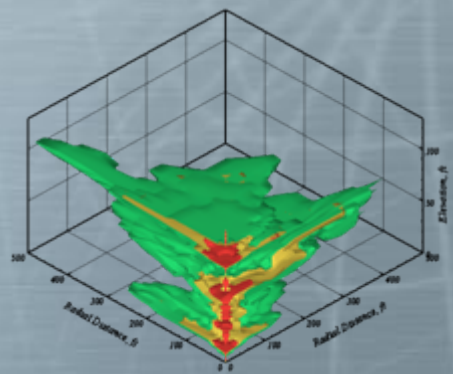


Objectives of Battelle's Piggyback Drilling Project

- Identify Formations of Interest for CO_2 Storage
- Improve Geologic Framework for Deep Formations
- Determine Geologic Patterns and Regional Distribution
- Focus on Formations Deeper than 3000'
- *Generate New Data for In-Depth Reservoir Research

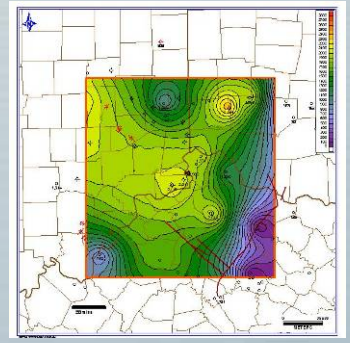


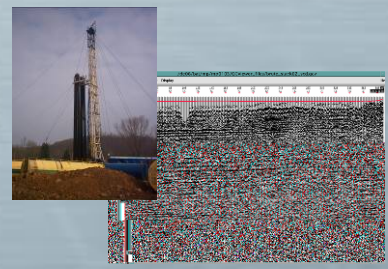


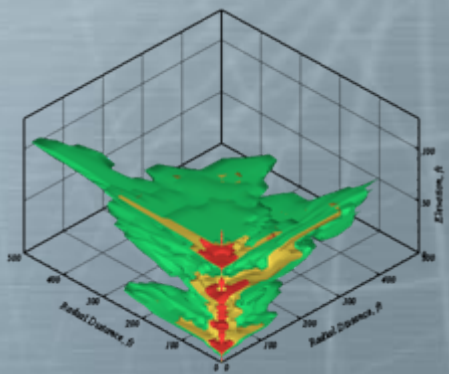


Approach of the Piggyback Drilling Project

- **Supplement or Extend Active Exploration Projects Through:**
  - Surface seismic surveys,
  - Adding a stratigraphic test tail on exploration wells
  - State-of-the-art wireline logging
  - Coring
  - Reservoir tests, brine sampling,
  - Petrographic, geochemical studies, etc.





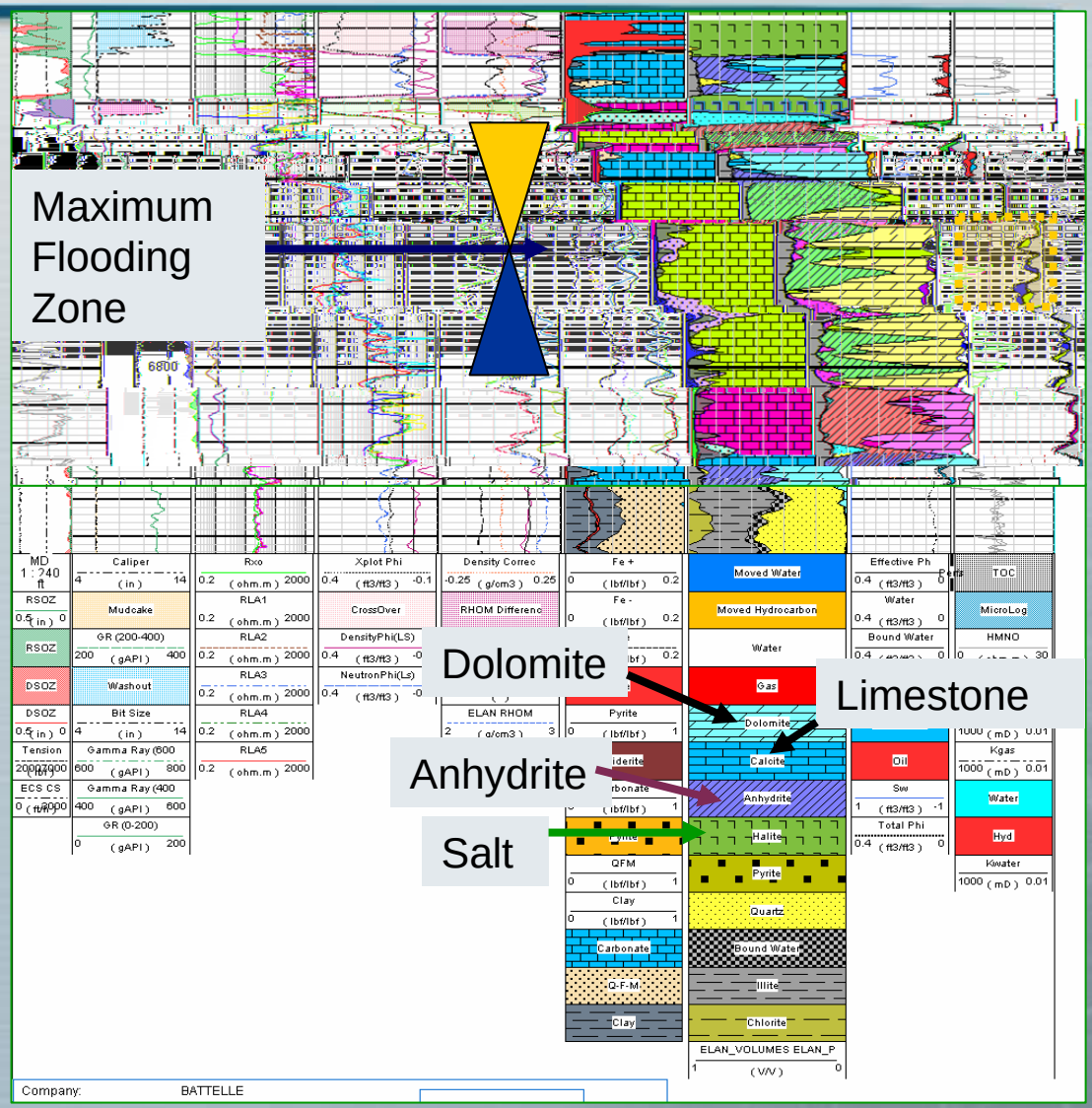


Sequence Stratigraphy Provides Model for Prediction of Porosity and Permeability

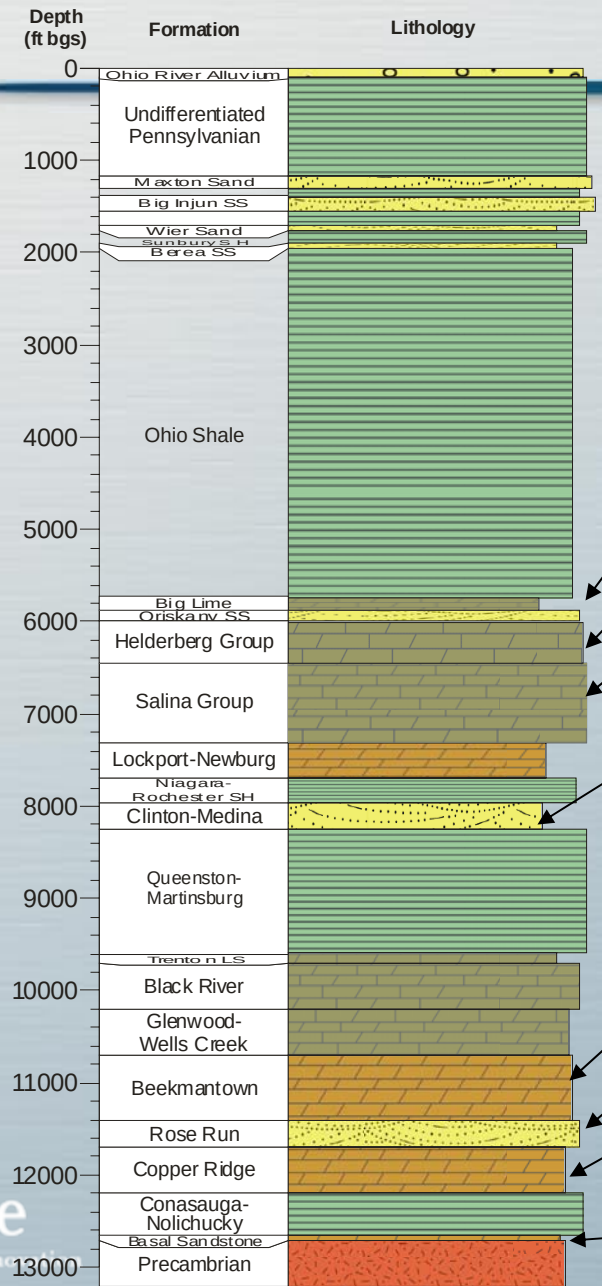
Example from Burger well: Newly identified Salina Williamsport porosity is in dolomites associated with Maximum Flooding Zones and provides a model for distribution in time and space

Salina Williamsport (6740-7038 ft)

-Logs show zones of porosity around 10%.
-Some short-lived gas shows
-Sandwiched between salt intervals.
-Porous dolomites above and below mappable Maximum Flooding Zone tight limestone.



Characterizing the Stratigraphic Column



Oriskany Sandstone

Bass Islands Dolomite

Salina Sub Group Dolomites

Clinton Sandstone

Beekmantown Erosional Highs

Rose Run Sandstone

Copper Ridge “B” Zone

Mt. Simon/Basal Sandstone

Zero Lost Time Incidents – Please be safe during the site visits!

Thank you!

Drilling at Mountaineer Plant, West Virginia